



# MODIS and VIIRS Instrument Status

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# Acknowledgements

## Contributions:

- MODIS Characterization Support Team (MCST)
- VIIRS Characterization Support Team (VCST)



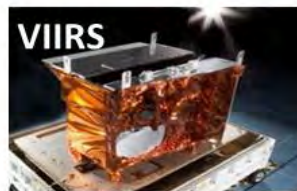
(photo taken in 2015)

## Support:

- Terra, Aqua, S-NPP, and JPSS (Flight) Projects
- Terra, Aqua, S-NPP, and NOAA-20 Flight/Mission Operation Teams (FOT/MOT)
- MODIS and VIIRS Instrument Vendor (Raytheon)
- MODIS and VIIRS Science Discipline Groups and Representatives
- NOAA JPSS Program and VIIRS SDR Team

# Contents

- Instrument Highlights
- On-orbit Performance
- Summary
- Future Activities
- Backup Slides (including L1B and data production status)



1999 →



2002 →



2011 →

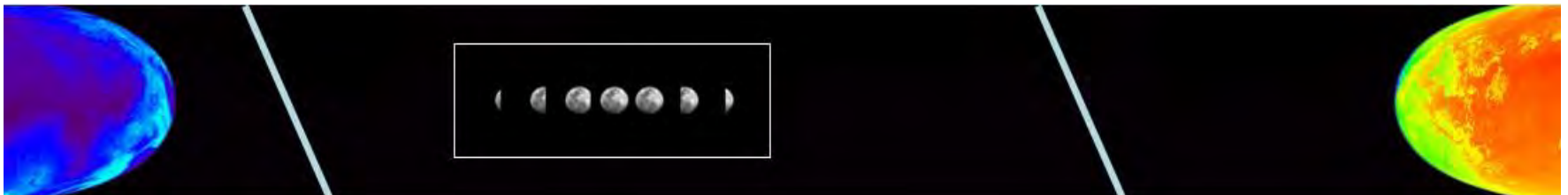


2017 →

# Instrument Highlights: Terra MODIS

## Instrument Operations and OBC Functions – Normal

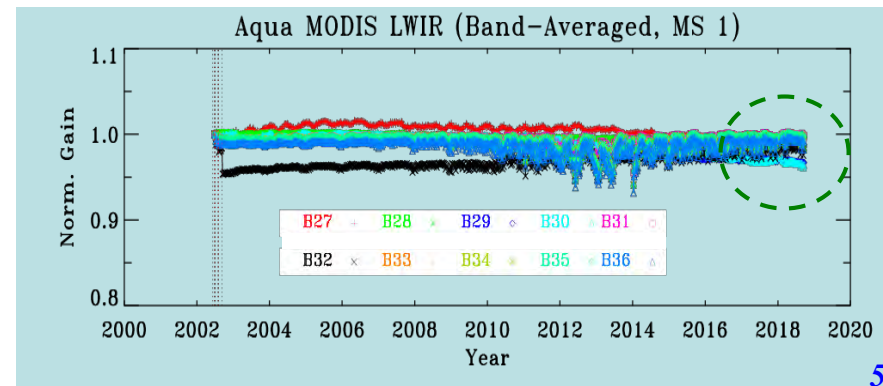
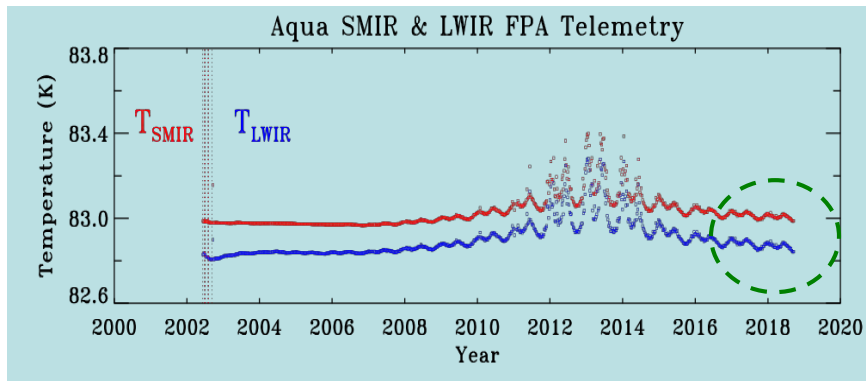
- No changes to instrument operational configuration since 2003 (current configuration: A-side electronics with B-side formatter)
- Successful recovery from Terra spacecraft (S/C) safe mode on Feb 18, 2016
  - Degraded performance of the PV LWIR bands (27-30) due to increased electronic crosstalk
  - Crosstalk impacts significantly reduced in C6.1 => science product improvements
- Support for Mission Extension Senior Review (2017)
- Changes made to the “DCR tables” to minimize the effect due to ADC uneven bin width (for bands 3, 4, 8, 10-12 with small SD view counts)
- Reduced frequency of PV ECAL and SRCA operations (no calibration impact)
- Terra S/C pitch maneuver (Aug. 5, 2017) with Moon views provided an excellent opportunity to validate sensor’s response versus scan-angle (RVS)



# Instrument Highlights: Aqua MODIS

## Instrument Operations and OBC Functions – Normal

- All B-side configuration since launch
- No new noisy detectors for Aqua MODIS since last STM
- SRCA lamp failure (no impact on L1B):
  - The 10W lamp #4 failed on June 30, 2016; one 10W lamp remains functional
  - Procedures (command scripts) developed and applied successfully to use the remaining 10W lamp in all the SRCA calibrations previously executed with the 20 and 30 W lamp configurations
- Support for Mission Extension Senior Review (2017)
- Reduced frequency of PV ECAL and SRCA operations (no calibration impact)
- Noticeable improvement in the control of Aqua MODIS CPFA temperatures

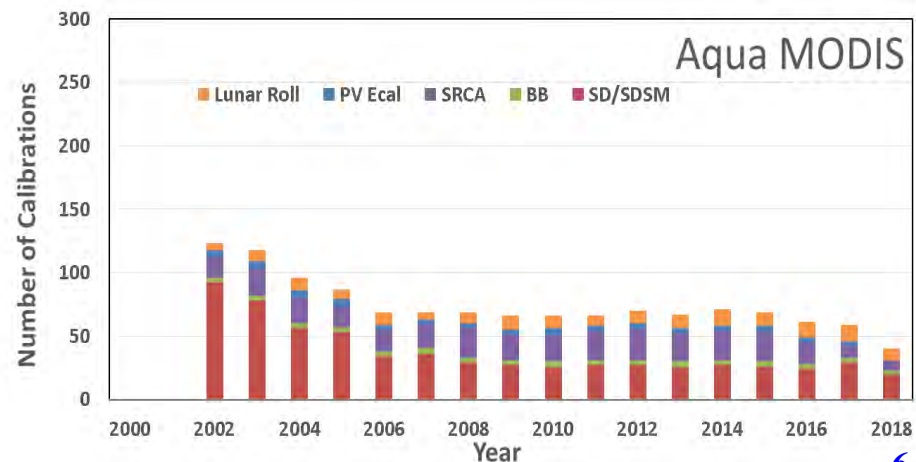
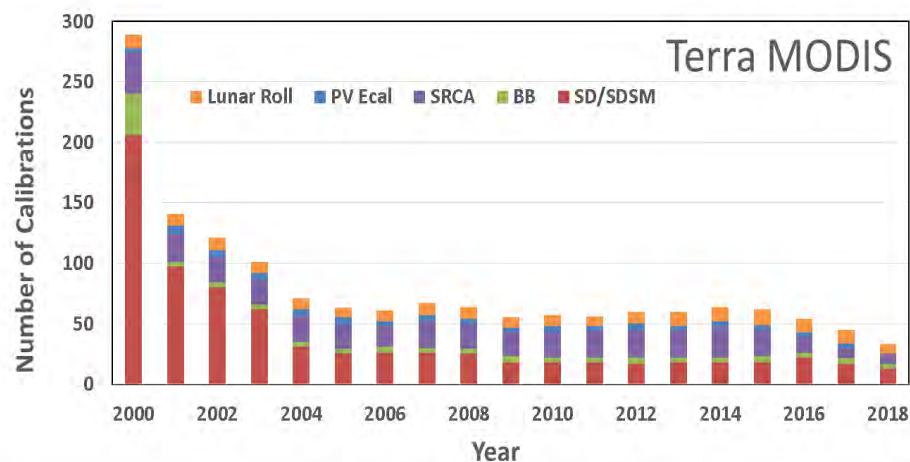
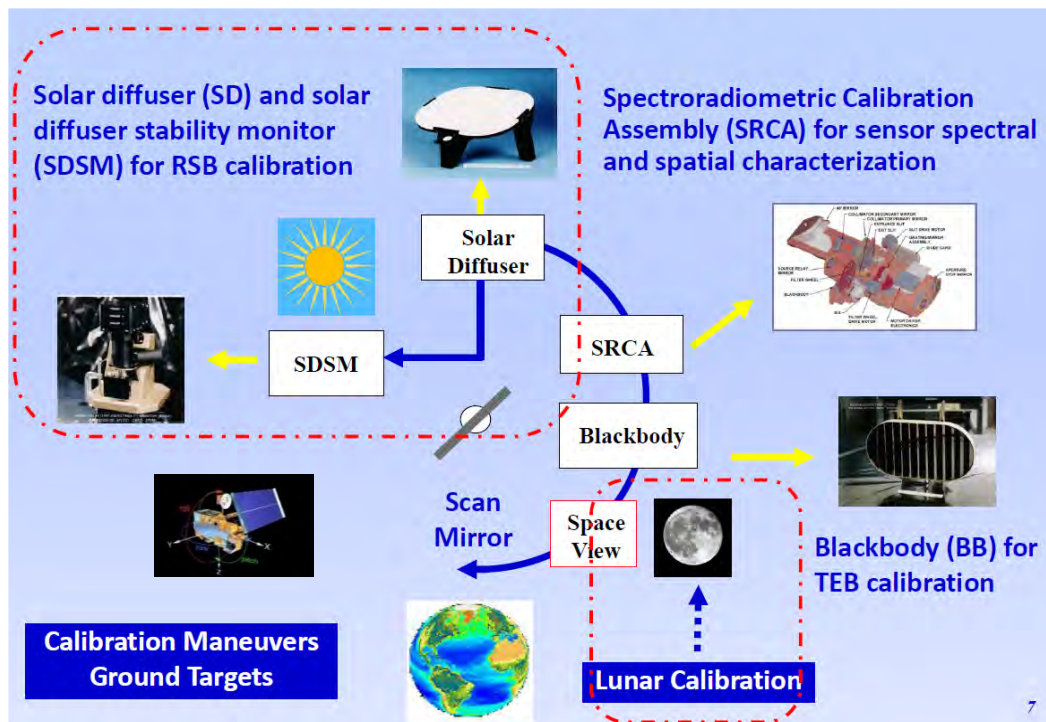


# MODIS Calibration Activities and LUT Updates

	Terra	Aqua
Lunar Roll:	188 (26)	165 (29)*
PV Ecal:	99 (3)	77 (6)
SRCA:	456 (23)	340 (25)
BB:	110 (11)	70 (9)
SD/SDSM:	755 (40)	635 (64)

(activities since last STM)\*

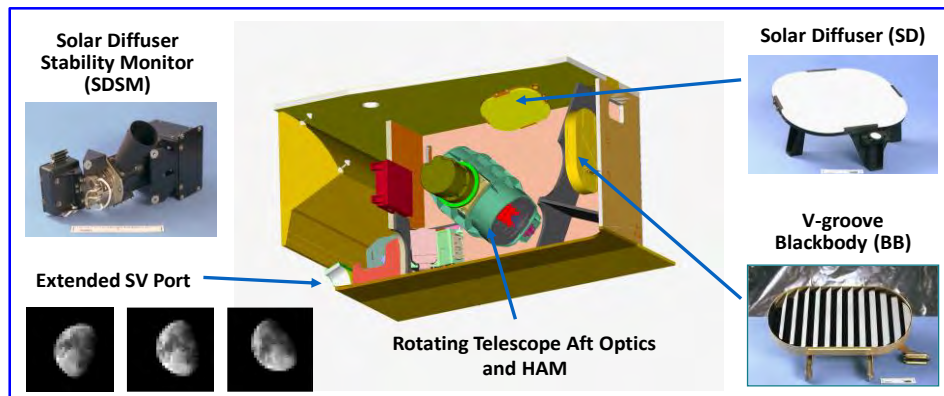
- LUT deliveries since last STM (C5/C6/C6.1/OBPG)
  - Terra MODIS: 9/32/23/2
  - Aqua MODIS: 11/34/19/21





# Instrument Highlights: S-NPP VIIRS

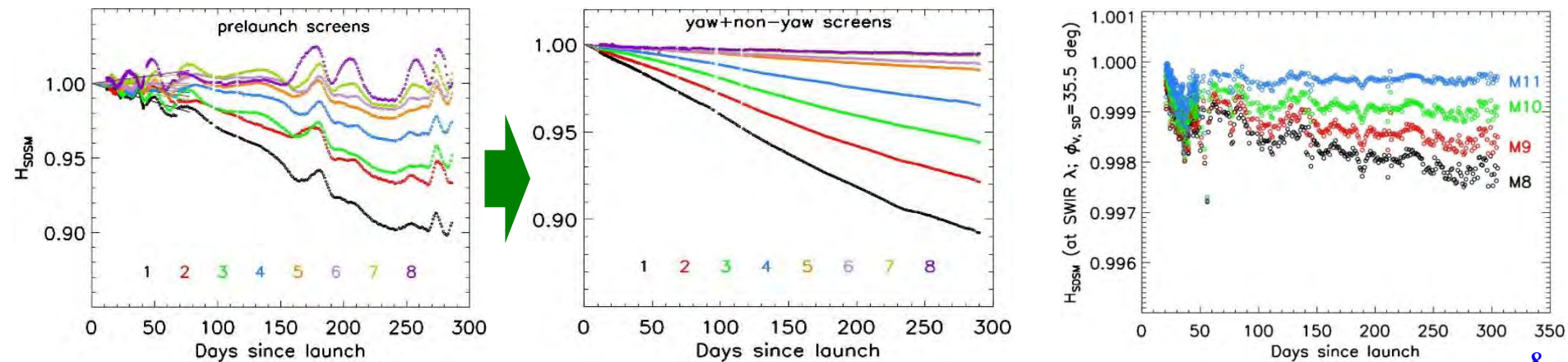
- **Instrument Operations and OBC Functions – Normal**
  - Scan Sync Loss between RTA and HAM: 96 since launch
  - Single Board Computer (SBC) lock-up: 13 since launch
- **On-orbit Calibration and SDR/L1B LUT Delivery**
  - New deltaC LUT applied in deriving RSB LUTs (starting from Apr. 24, 2018)
  - H-factors (SD degradation) correction for solar azimuth dependence applied to VIS/NIR bands
  - Use of lunar F-factors for RSB calibration improvements
  - 65/**53** sets of LUTs delivered for Land SIPS processing of SDR C1.0 – C2.0 (Oct. 2012 – present)/**L1B V1.1 – V3.0** (Jan 2016 – present)



- SD calibration: each orbit
- SDSM: 3 times/week
- BB WUCD: 26 since launch
- DNB VROP: monthly
- Lunar observations: 59 since launch

# Instrument Highlights: NOAA-20 VIIRS

- **Instrument Operations and OBC Functions – Normal**
  - Scan Sync Loss between RTA and HAM: 18 since launch
- **On-orbit Calibration and SDR/L1B LUT Delivery**
  - Use of yaw and regular on-orbit data to improve the pre-launch screen transmission
  - H-factor also applied for SWIR using degradation model developed from S-NPP
  - Initial ice buildup on LWIR FPA removed via an outgassing => restore TEB gains
  - 3 sets of LUTs delivered to Land SIPS for L1B processing using V3.0 software (June 2018 – present)



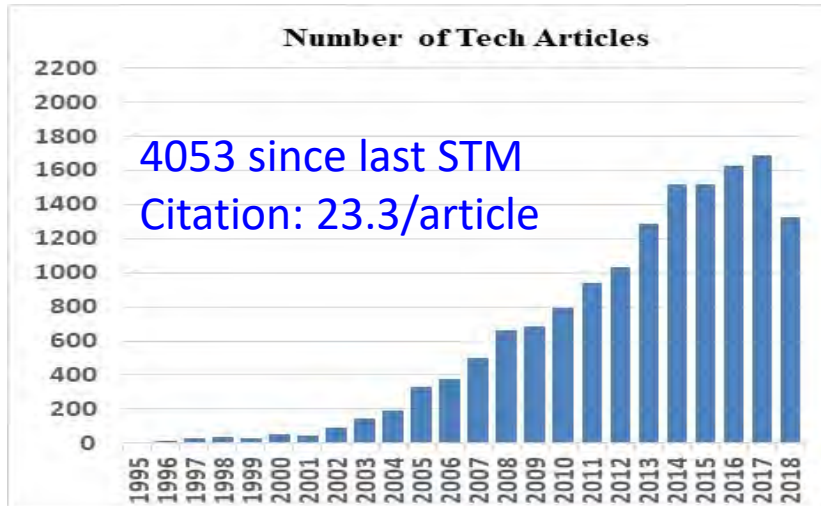


# MODIS and VIIRS Publications

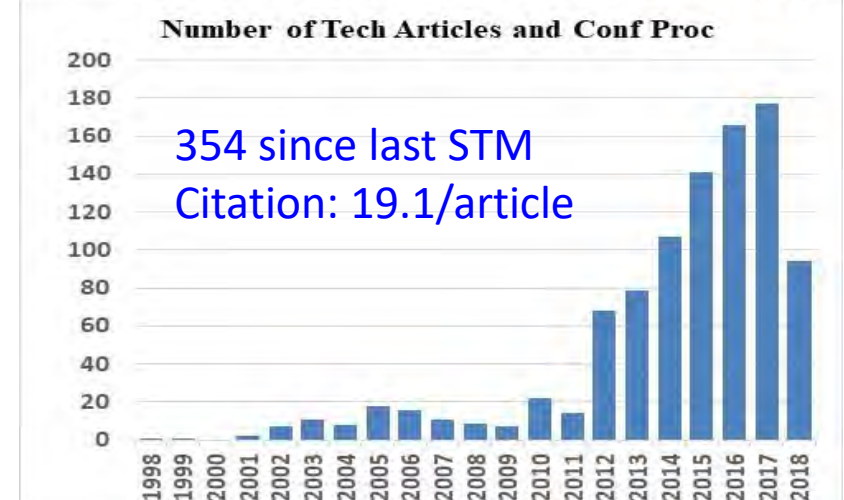
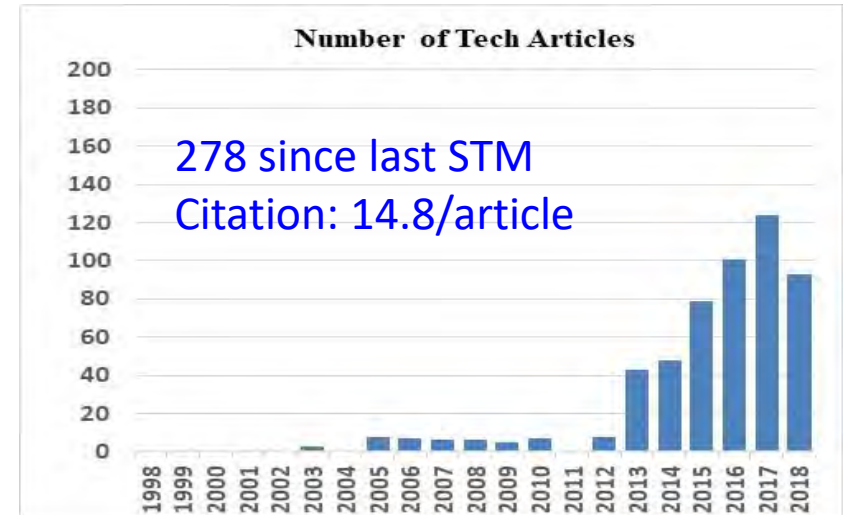
**MODIS:** 14959 tech articles and 19806 tech article and proc. combined

**VIIRS:** 542 tech articles and 959 tech article and proc. combined ([Web of Science](#))

## MODIS



## VIIRS



# Current Plan for Terra and Aqua Spacecraft Operation

## Terra Spacecraft

- Continue operations at its current crossing time and altitude through the last inclination burns planned for October 2020
- Current plan is to exit the 705-km constellation when Terra's crossing time reaches 10:15 am currently predicted for January 2022
- Current predictions are for Terra to reach 9:00 am crossing time in Spring 2026 (9:00 am crossing time is used as a placeholder based on passivation of EO-1)



**1.6 million data user**

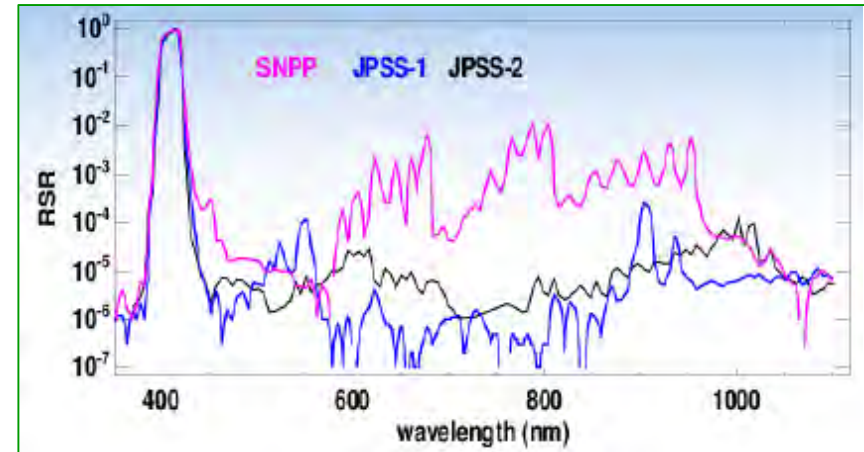
## Aqua Spacecraft

- Continue operation at its current position in the Afternoon Constellation (aka the A-Train) through early 2022.
- Current plans are for Aqua to exit the A-Train in early 2022 and immediately proceed to lower its orbit perigee such that Aqua will reenter the atmosphere within 25-years, an Agency and International requirement.
- Plan to continue science operations in the new lower orbit as long as the instruments are capable of providing good science.

# VIIRS on JPSS-2, -3, and -4

## JPSS-2 VIIRS

- Ambient test completed in Aug. 2016
- Sensor TVAC completed in Sept. 2017
- Pre-Ship Review: March 28-29, 2018
- Delivery to S/C vendor: Feb. 2019
- Launch: 2022

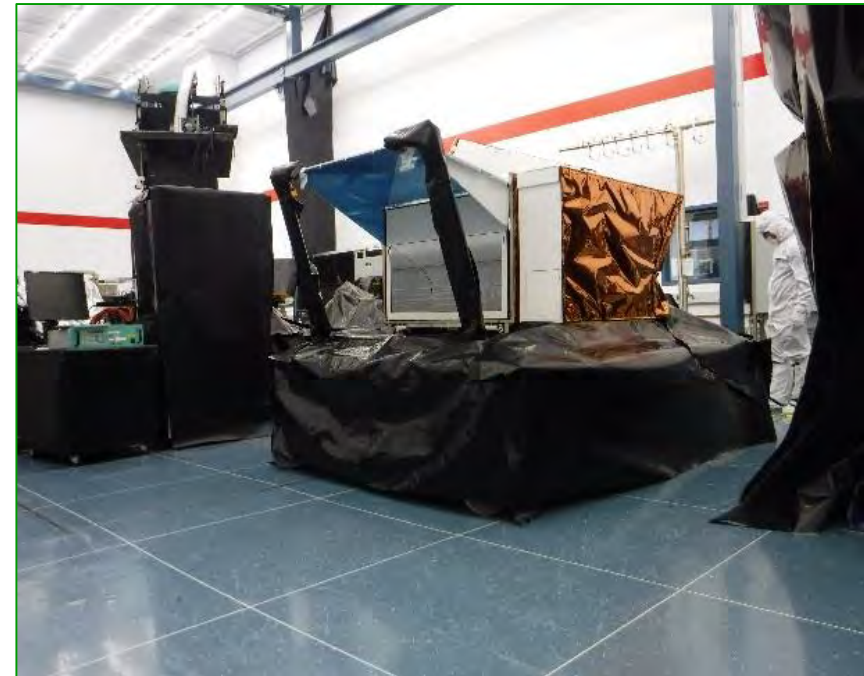


## JPSS-3 VIIRS

- Ambient and TVAC: April 2019 - 2021
- Launch: 2026

## JPSS-4 VIIRS

- Ambient and TVAC: July 2020- 2022
- Launch: 2031



# Technical Meetings and Workshops

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- MODIS and VIIRS Calibration Workshop
  - 1:00 pm - 5:20 pm, Oct 18, 2018
  - 8:10 am - 12:00 pm, Oct 19, 2018
- Bi-weekly MsWG meetings (also joined by VCST)
  - MODIS Crosstalk Assessment Workshop (Aug. 1, 2018)
  - Aqua MODIS CFPA Performance Briefing (Sept. 26, 2018)
- Regular TIMs with OBPG (MCST and VCST)
- Special TIMs with science groups on specific calibration topics
- VIIRS Level-1 Algorithm/Software Working Group meetings
- VIIRS SDR meetings (led by NOAA STAR)

# Terra and Aqua MODIS On-orbit Performance

- **Instrument and On-board Calibrators (OBC)**

- Terra MODIS: VIS/NIR FPA temperature increase: < 3.5 K; CFPA temperatures: very stable; BB temperature increase: < 30 mK; SD degradation: faster than Aqua MODIS (SD door fixed at open since 2003)
- Aqua MODIS: VIS/NIR FPA temperature increase: < 2.0 K; **CFPA temperatures: improved control**; BB temperatures: extremely stable; SD degradation: slower than Terra MODIS

- **Radiometric (**Terra PV LWIR improvements**)**

- Spectral band responses
- Detector noise characterization

- **Spatial and Spectral (no change since last STM)**

- Band-to-band registration (BBR): continue to be stable
- Center wavelengths and bandwidths: changes are within 0.5 nm and 1.0 nm, respectively, for most VIS/NIR bands; relatively large changes for bands with broad bandwidths (bands 1, 17, 19)

- **Geolocation**

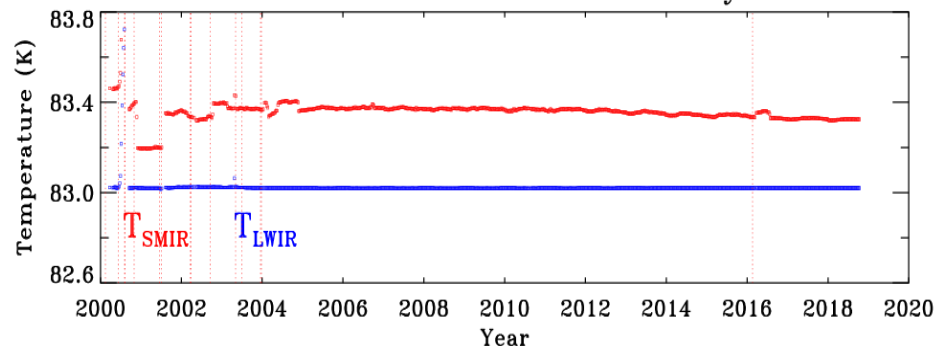
- **Improvements made in C6.1**



# MODIS CFPA, BB Telemetry, and SD Degradation

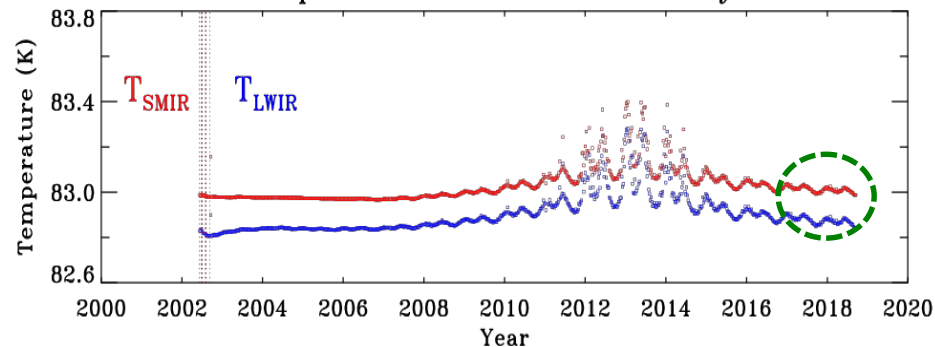
## Terra MODIS

Terra SMIR & LWIR FPA Telemetry

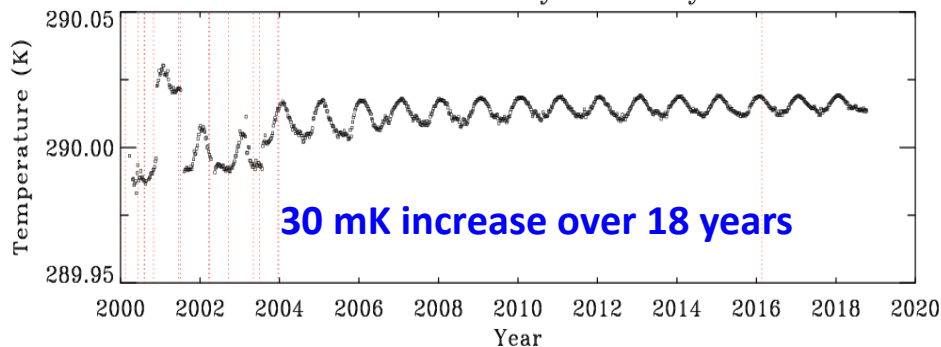


## Aqua MODIS

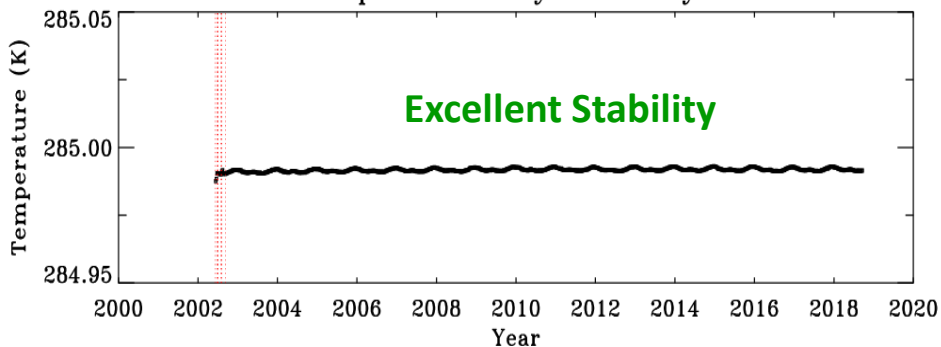
Aqua SMIR & LWIR FPA Telemetry



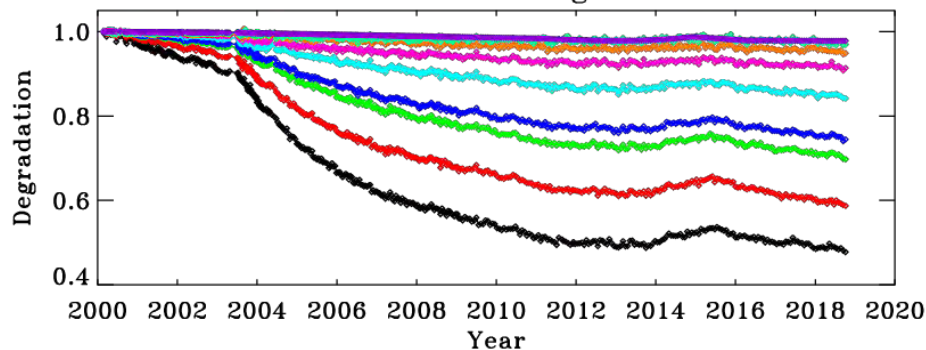
Terra Blackbody Telemetry



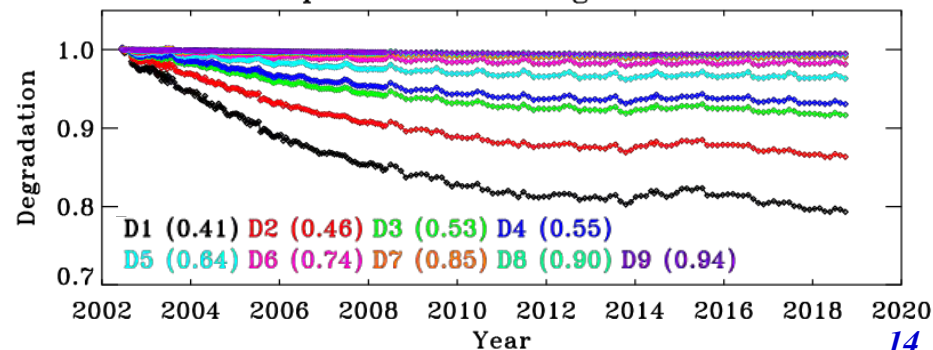
Aqua Blackbody Telemetry



Terra MODIS SD degradation

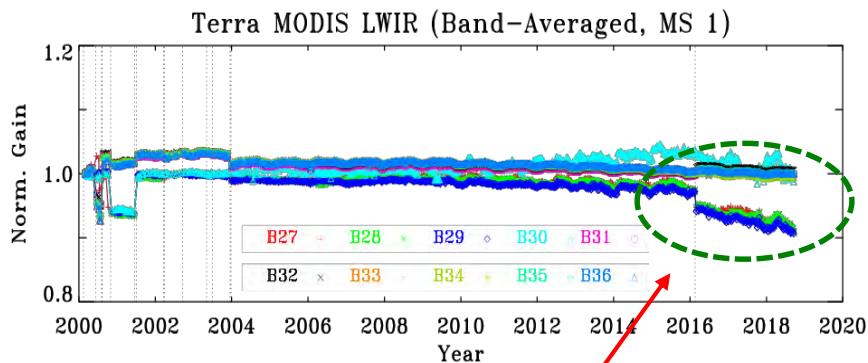
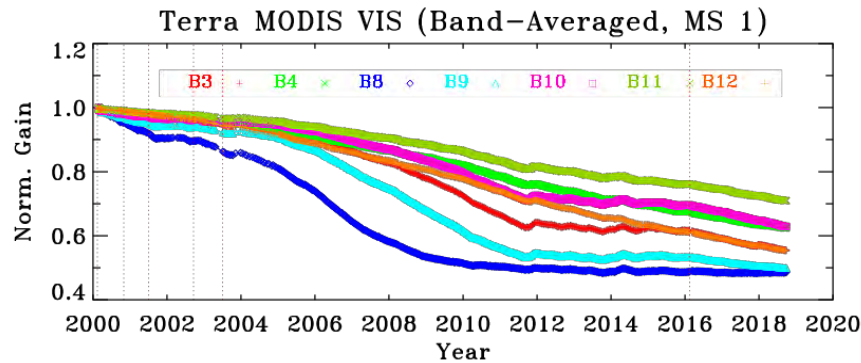


Aqua MODIS SD degradation



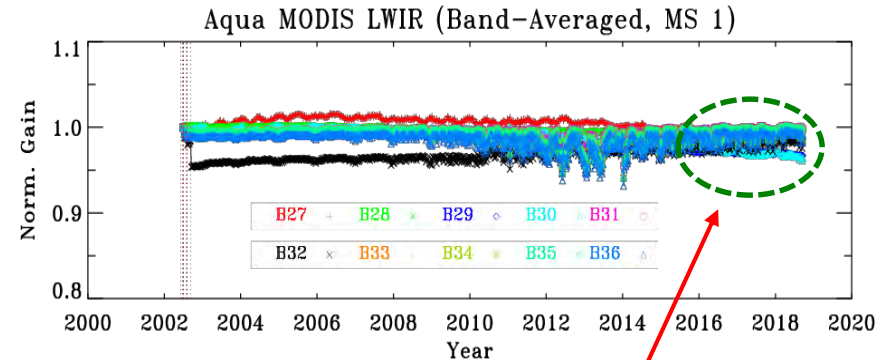
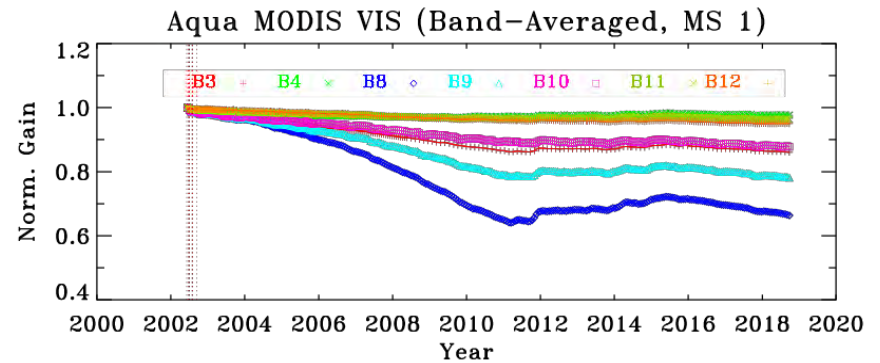
# MODIS Spectral Band Responses (Gains)

## Terra MODIS



Terra PV LWIR performance  
restored in C6.1

## Aqua MODIS



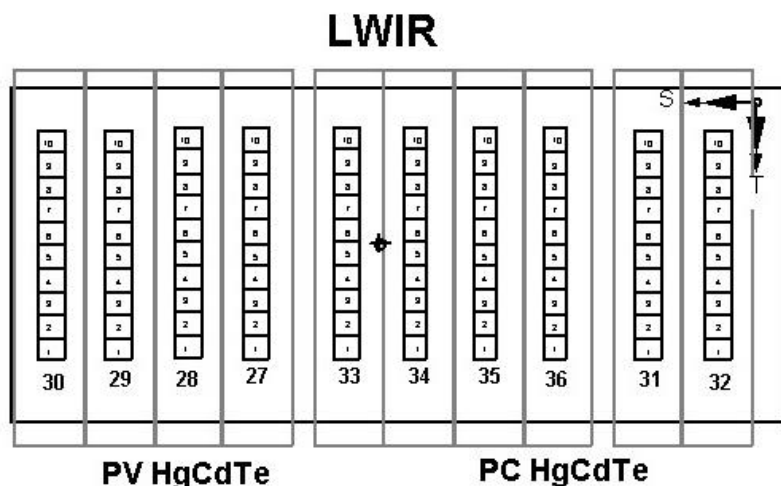
More stable for Aqua PC  
LWIR responses

All MODIS spectral band responses (RSB and TEB) are provided in backup slides

# MODIS Detector Noise Characterization

**MODIS: 36 spectral bands (on 4 FPAs); a total of 490 individual detectors**

- Terra MODIS (at last STM): 53 noisy detectors (30 from pre-launch; 35 at launch) and 3 inoperable detectors (all in PV LWIR); 21 of the 26 noisy and inoperable detectors since launch were in LWIR PV bands; 11 of the 21 occurred after the SC safe hold event in Feb 2016
- Terra MODIS (currently): 39 noisy detectors (30 from prelaunch; 35 at-launch) and 1 inoperable detector (D6 in B29). **The performance of the detectors in the PV LWIR bands restored after xtalk correction in C6.1**
- Aqua MODIS: 10 noisy detectors (2 from pre-launch; 3 at launch) and 15 inoperable detectors (13 in Band 6) – **no change since last STM**

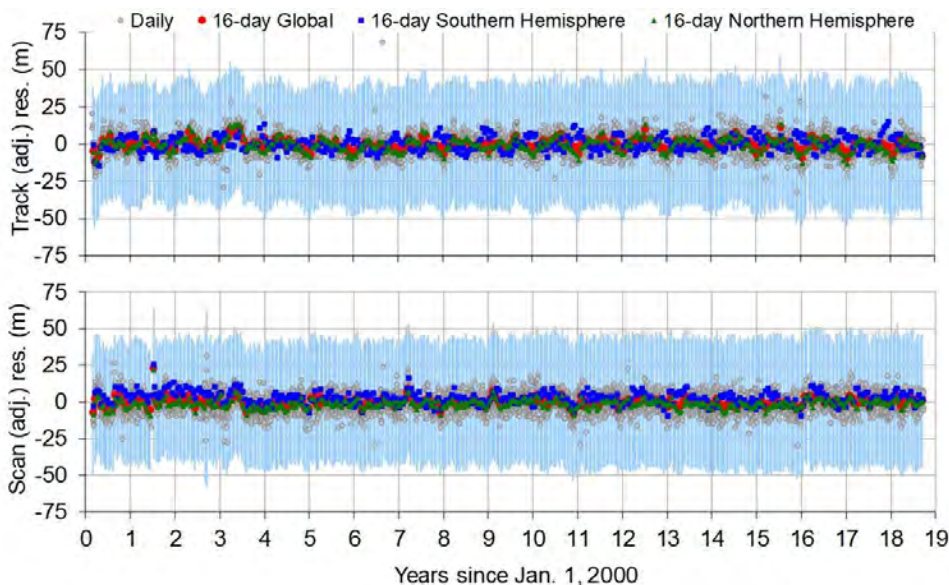


Terra MODIS: performance of some TEB PV LWIR detectors restored after the crosstalk correction implemented in C6.1.  
Corresponding QA LUT also updated

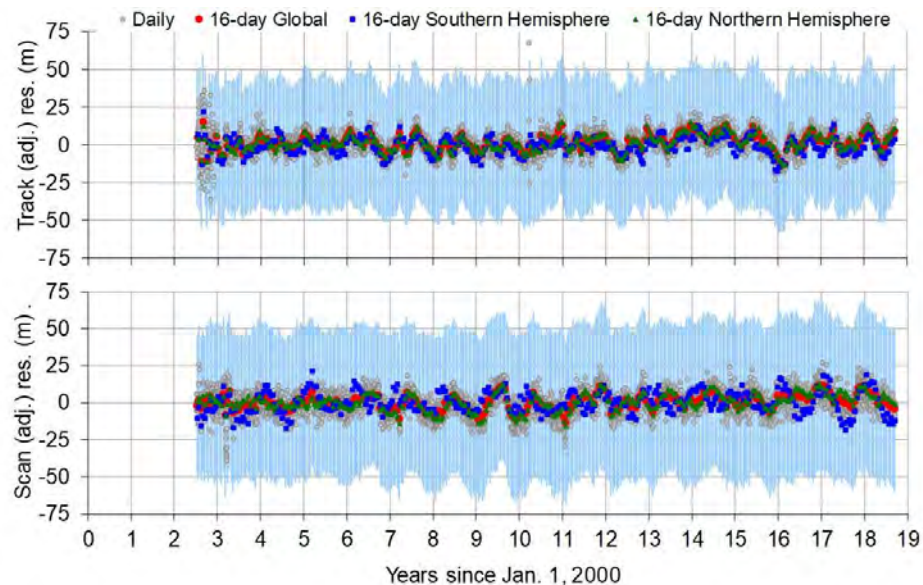
# MODIS Geolocation Performance (C6.1)

- Terra and Aqua MODIS geolocation performance remains excellent
- No changes in track or scan RMSE since last STM

**Track: 43 m; Scan: 44 m (Terra MODIS)**



**Track: 46 m; Scan: 53 m (Aqua MODIS)**



• Daily • 16-day Global • 16-day Southern Hemisphere • 16-day Northern Hemisphere

- Terra track direction jump in C6 (due to a delayed update of Geo LUTs) from 01/01/2013 to 08/10/2013 has been removed in C6.1.
- Aqua track direction jump in C6 at the end of 2011 has also been removed in C6.1 LUTs.

# VIIRS On-orbit Performance

- **Instrument and On-board Calibrators (OBC)**

- S-NPP: VIS/NIR FPA temperature: stable; LWIR CFPA temperature: stable; SMIR CFPA temperature: increased by 50mK since launch; BB stability: very stable; SD degradation: faster than Aqua MODIS
- NOAA-20: VIS/NIR FPA temperature: stable; CFPAs temperatures: stable; BB stability: very stable; SD degradation: **slightly smaller than S-NPP**

- **Radiometric**

- SNRs well above requirements except N20 band 13 detector 29 (noisy)
- S-NPP: **detector gain decrease in the RSBs has leveled off**, TEB gains remain stable
- NOAA-20: RSB detector gains remain nearly flat, **TEB gains recovered and remain nearly flat after the mid-mission outgassing**
- DNB stray light correction for both S-NPP and NOAA-20

- **Spatial and Spectral (no change since last STM)**

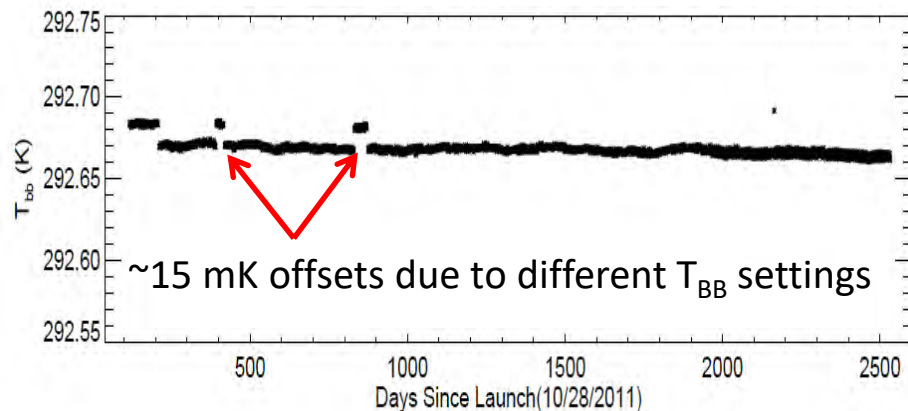
- Band-to-band registration (BBR) has been stable since launch for both S-NPP and NOAA-20 VIIRS

- **Geolocation**

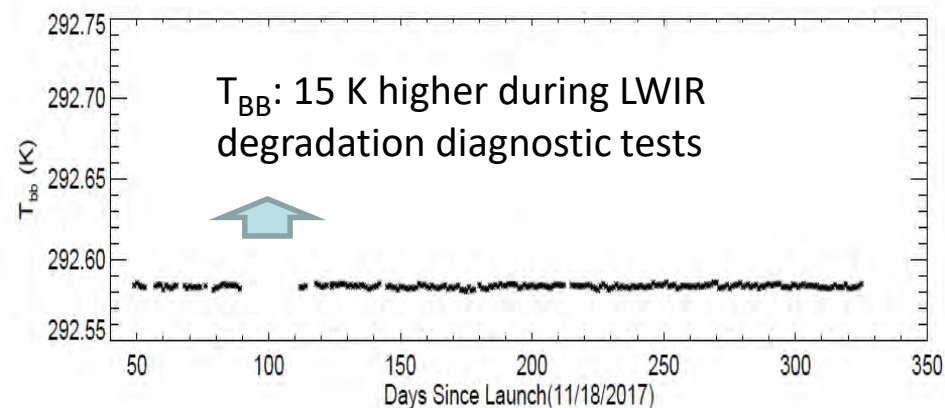


# VIIRS BB Temperature and SD Degradation

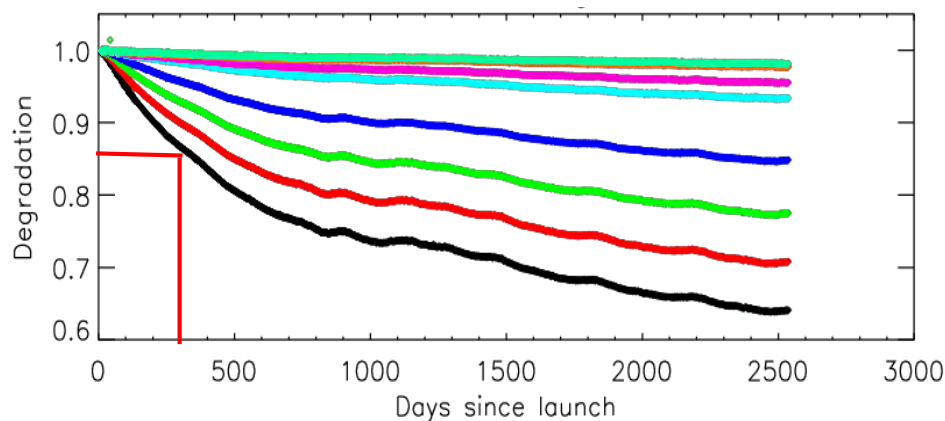
## S-NPP BB Temperatures



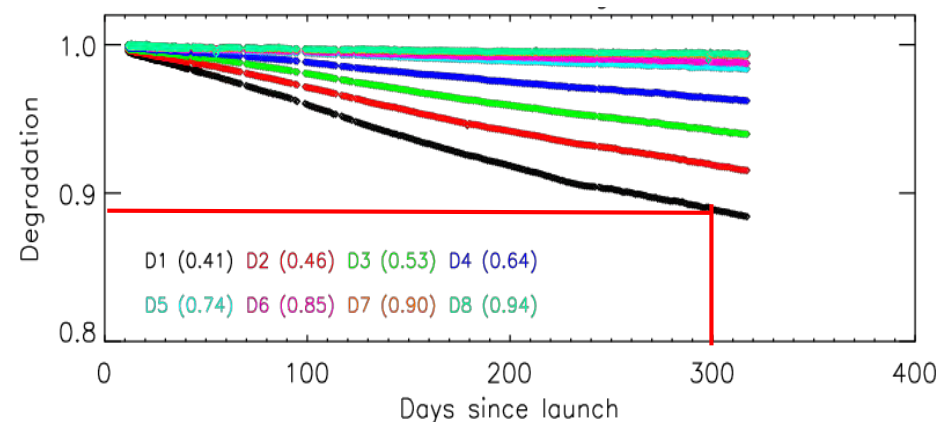
## NOAA-20 BB Temperatures



## S-NPP SD Degradation



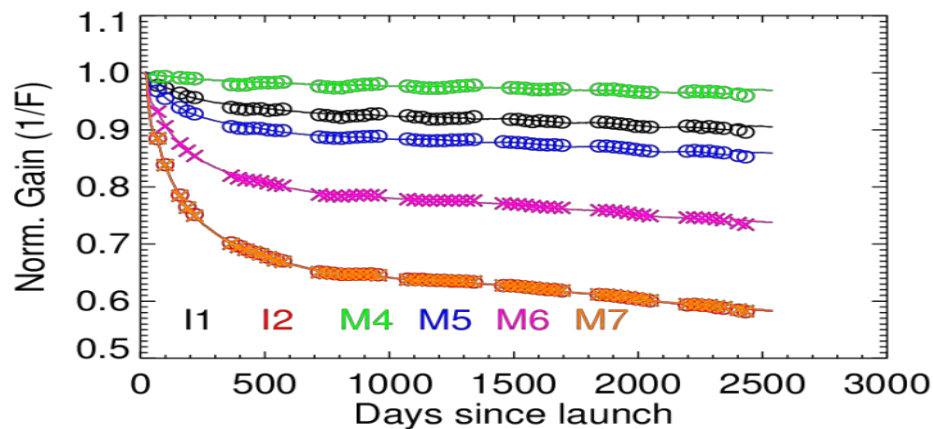
## NOAA-20 SD Degradation



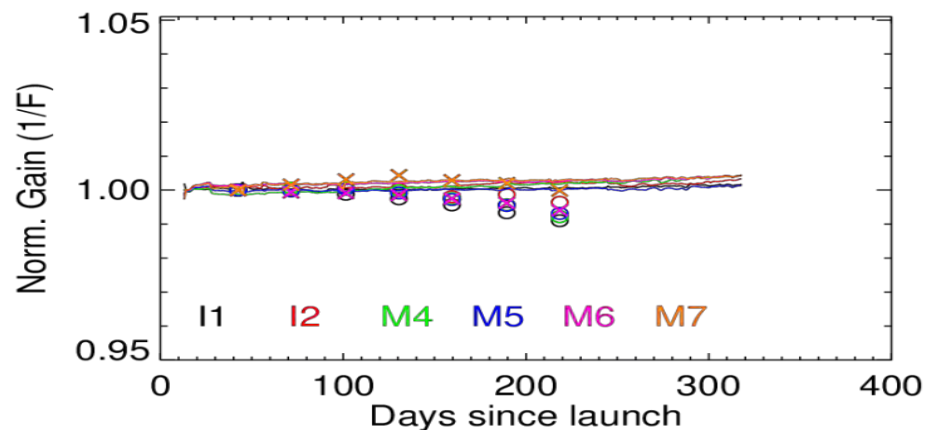
N-20 SD degradation is slightly smaller than S-NPP over the same performance period

# VIIRS Spectral Band Responses (Gains)

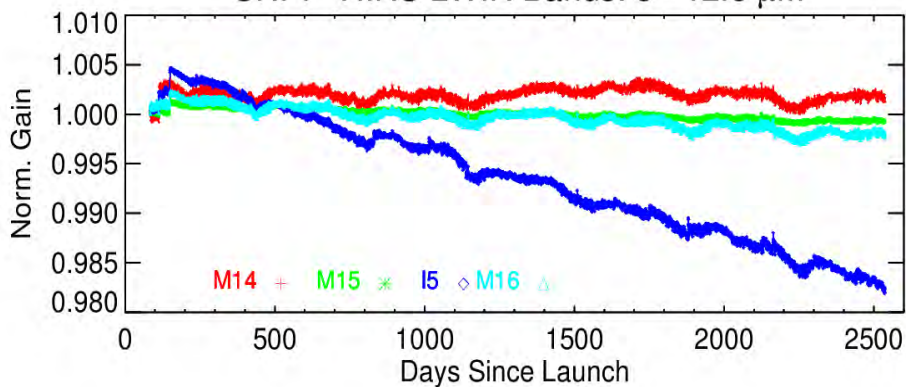
## S-NPP VIIRS



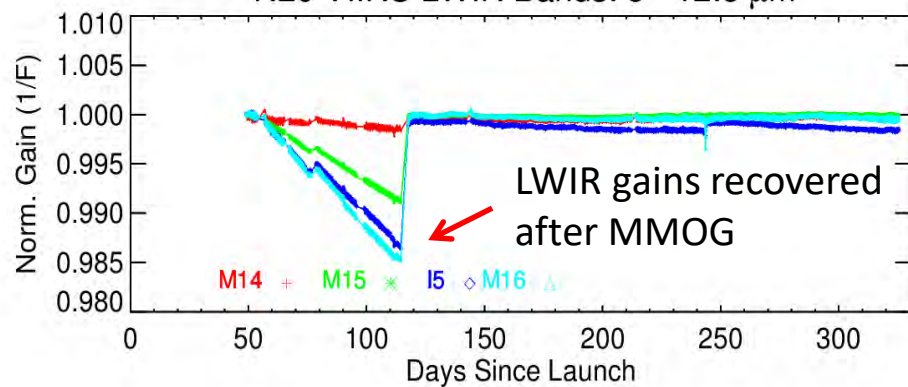
## NOAA-20 VIIRS



## SNPP VIIRS LWIR Bands: 8 - 12.5 $\mu\text{m}$



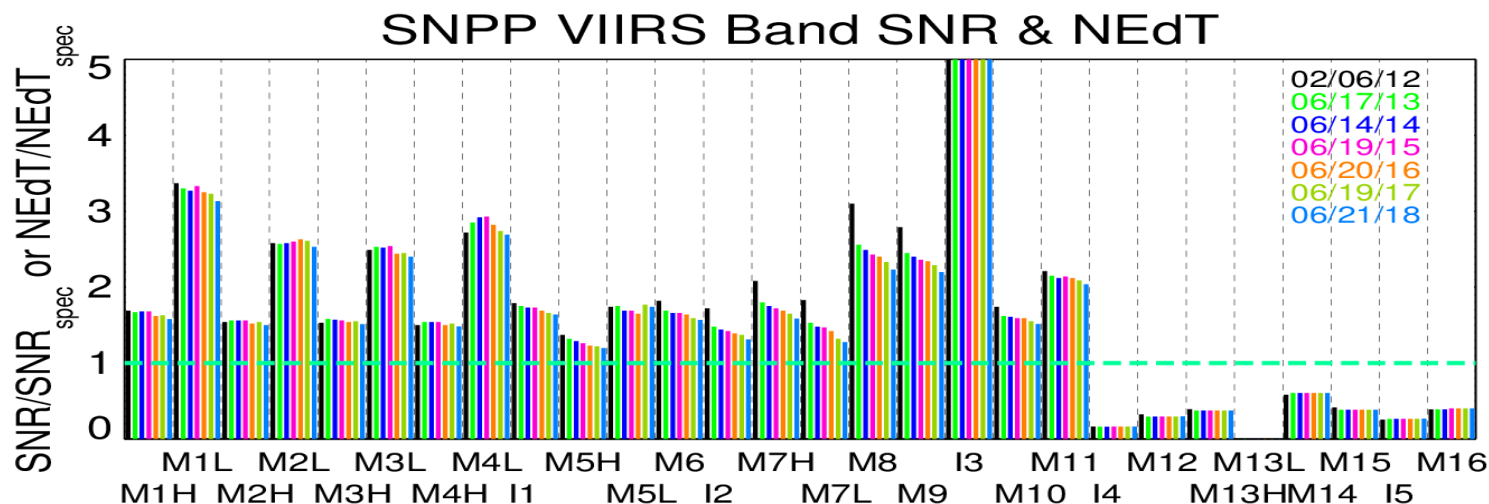
## N20 VIIRS LWIR Bands: 8 - 12.5 $\mu\text{m}$



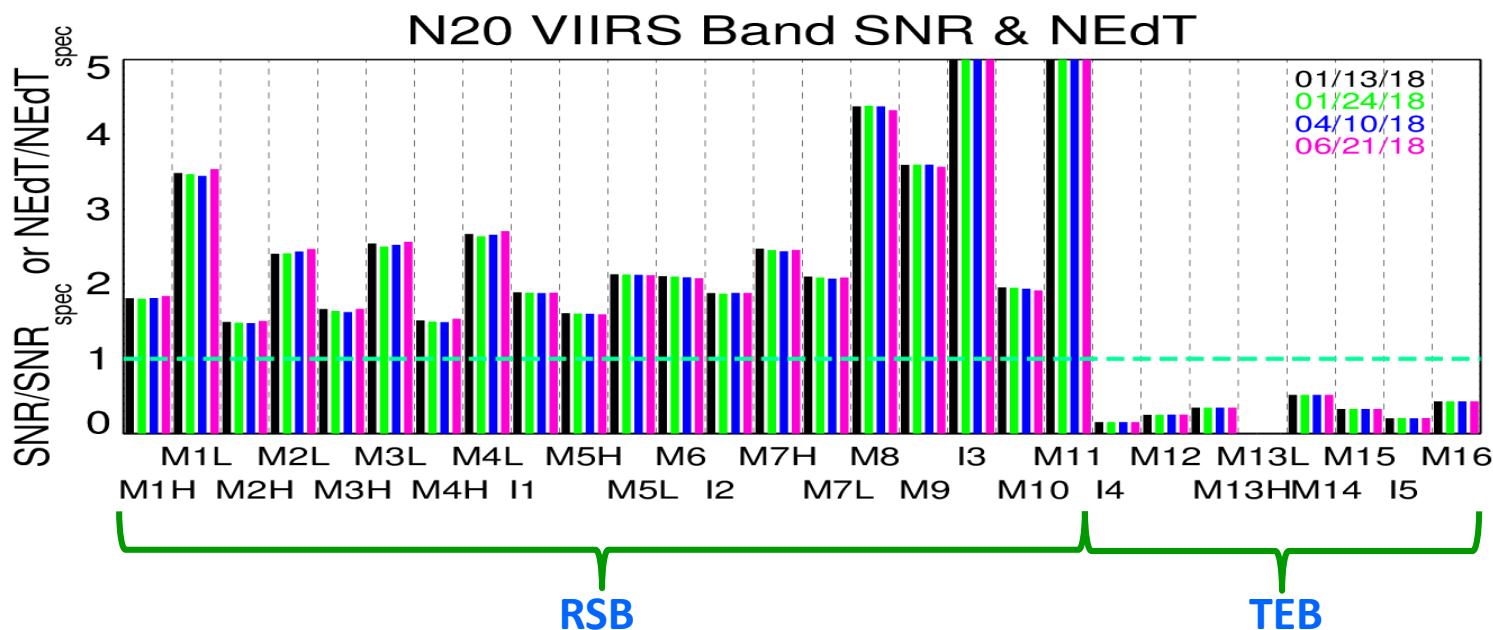
All VIIRS spectral band responses (RSB and TEB) are provided in backup slides

# VIIRS Detector Noise Characterization

RSB:  $\text{SNR}/\text{SNR}_{\text{SPEC}} > 1$  or TEB:  $\text{NEdT}/\text{NEdT}_{\text{SPEC}} < 1 \Rightarrow$  meet specified requirements



No noisy det.  
in S-NPP

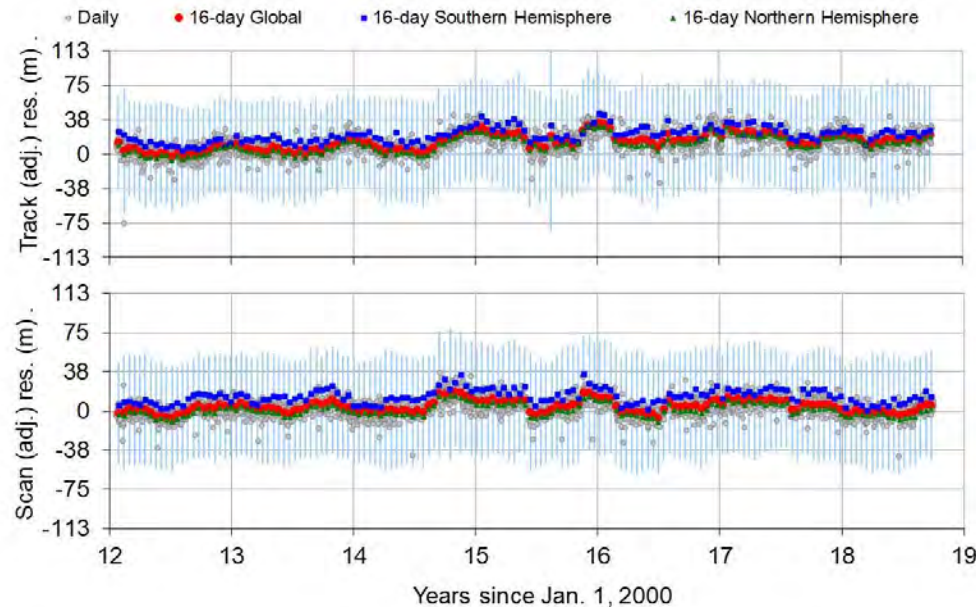


Noisy det.: I3  
D29 in N-20

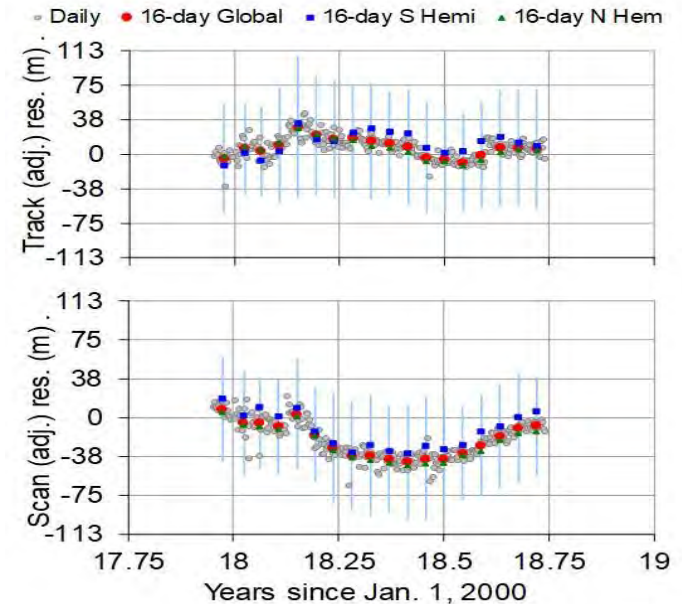
# VIIRS Geolocation Performance

- S-NPP VIIRS geolocation performance has been stable
- Effort is being made to improve NOAA-20 VIIRS geolocation performance

**Track: 58 m; Scan: 52 m (S-NPP VIIRS C1)**



**Track: 62 m; Scan: 59 m (NOAA-20 VIIRS)**



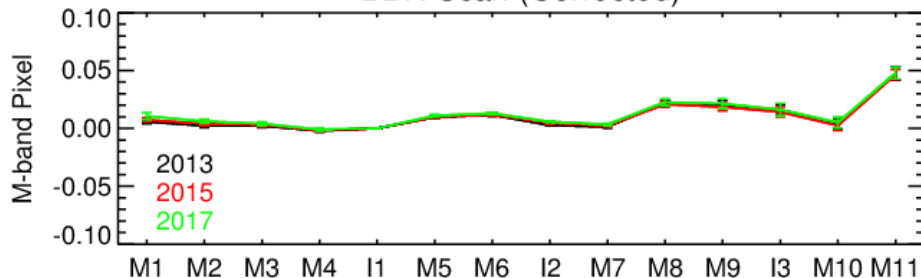
• Daily • 16-day Global • 16-day Southern Hemisphere • 16-day Northern Hemisphere

- J1 pointing variation is larger than S-NPP. Yaw and pitch pointing variation causes geolocation error  $\sim 250$  m near the end of scan.
- MODIS-like correction is being worked

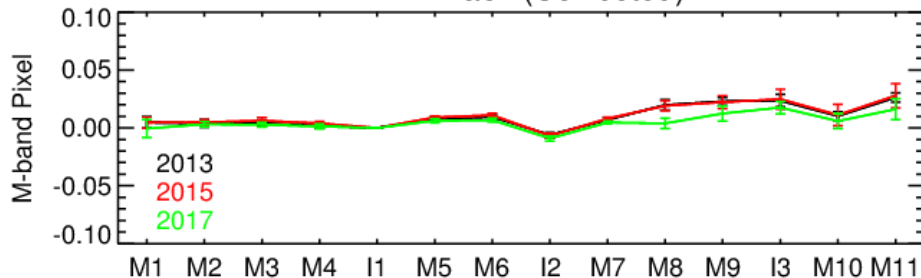
# VIIRS Spatial Characterization (BBR)

## S-NPP VIIRS

BBR Scan (Corrected)

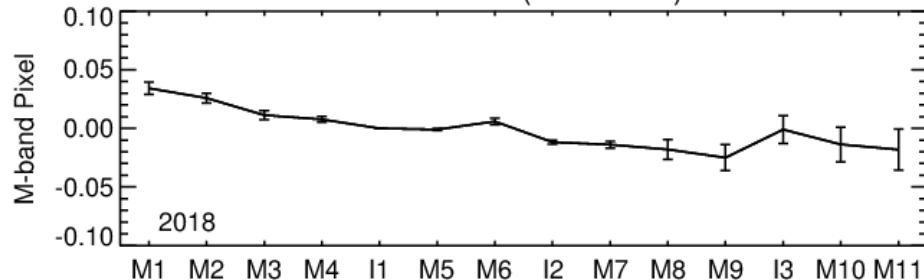


BBR Track (Corrected)

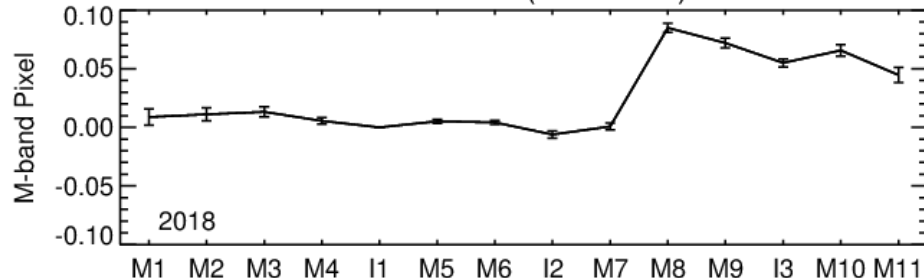


## NOAA-20 VIIRS

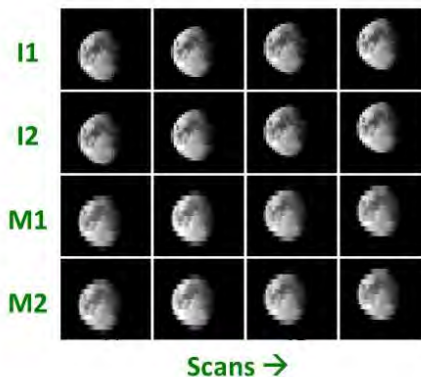
BBR Scan (Corrected)



BBR Track (Corrected)



Lunar images (S-NPP, 05/25/18)



- Methodology developed for MODIS BBR characterization using lunar observations and validated using MODIS on-board SRCA
- On-orbit BBR is very stable in both scan and track directions



# VIIRS DNB Stray Light Correction

S-NPP DNB: 08:35:00, 07/13/2018  
(North America)

N20 DNB: 07:44:45, 07/13/2018  
(North America)

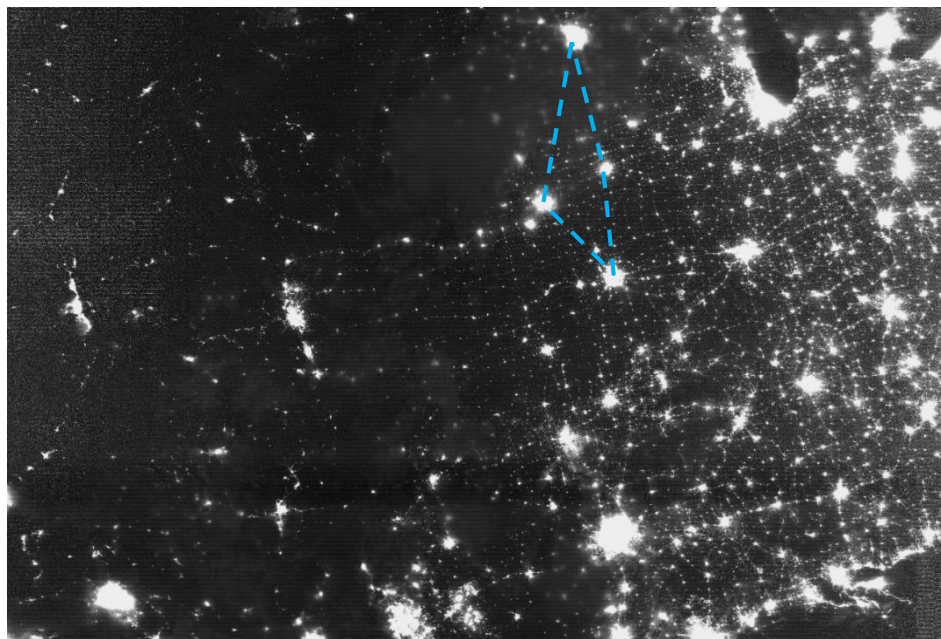


**Before stray light correction**

# VIIRS DNB Stray Light Correction

S-NPP DNB: 08:35:00, 07/13/2018  
(North America)

N20 DNB: 07:44:45, 07/13/2018  
(North America)



**After stray light correction**

# Summary

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- Both Terra (18 years) and Aqua (16 years) MODIS and their OBC continue to operate and function normally
- Both S-NPP (~7 years) and NOAA-20 (~1 year) VIIRS and their OBC continue to operate and function normally
- Efforts by MCST and VCST, including support from SDST, SIPS, and science algorithm developers, remain critical to ensure and improve sensor calibration and data quality
- Challenging issues identified for both MODIS and VIIRS will be investigated and addressed for future calibration improvements in support of their data processing/reprocessing
- More efforts are needed to better understand the calibration differences among sensors (S-NPP and NOAA-20 VIIRS; VIIRS and Aqua MODIS) and to help generate consistent data products of high quality

# Future Activities: MODIS

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- Track changes in VIS/NIR RVS, including the use of alternative approaches and techniques
- Monitor changes in Terra MODIS polarization sensitivity and evaluate its impact on the earth view response trending, including the use of newly developed methodology to correct for polarization impact in the RVS calculations (implementation strategy to be approved/accepted)
- Improve the SWIR band optical leak and crosstalk characterization involving algorithm improvement and use of different sending band (Terra MODIS from B28 to B25) to avoid crosstalk contamination
- Constantly monitor and update if necessary the PV LWIR electronic crosstalk in Terra MODIS
- Propose, test, and apply crosstalk correction for other TEB bands/detectors in C7 (an in-depth assessment of the crosstalk in TEB of both instruments has completed; bands/detectors requiring this correction have been identified including correction strategy).

**More details to be presented at the MODIS and VIIRS Calibration Workshop**

# Future Activities: VIIRS

- **Calibration Efforts**

- S-NPP:
  1. apply positional dependence of the H-factor
  2. track potential changes in VIIRS RVS
- NOAA-20
  1. study angular dependence of the H-factor
  2. improve the screens with more regular on-orbit data
  3. examine positional dependence of the H-factor
  4. develop and apply DNB stray light correction for the extended area (end of scan)
- S-NPP/N20 calibration bias: ~2-4% from SNOs

- **L1B Algorithm and LUT Improvements**

- POC: Fred Patt and Vincent Chiang
- Latest effort on L1 V3 SW (details in Calibration Workshop materials)

**More details to be presented at the MODIS and VIIRS Calibration Workshop**



# Backup Slides

# MODIS L1B and Atmosphere Processing Status

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- **C6 (L1B and Land) and C61 (L1B and Atmosphere) forward processing are typically 1-2 days behind real time.**
- **C61 reprocessing of L1/L1B, Geolocation and Atmosphere**
  - Terra: started in June 2017 and completed in Dec 2017
  - Aqua: started in Sep 2017 and completed in Mar 2018
- **Processing of C6 L1B is expected to continue until the end of C61 Land reprocessing (Summer of 2019).**
- **C6/C61 L1B and C61 Atmosphere products are available to public from NASA LAADS DAAC.**
- **NRT processing (C61 Atmosphere and C6 Land) is completed typically 2 to 2.5 hours after acquisition of data.**
- **MCST continues to derive and deliver forward LUT updates for the two processing streams (C6 and C61) as needed.**

# S-NPP VIIRS L1B Processing Status

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- **V1 forward processing of L1B SDR and V2 forward processing of NASA L1B are typically 1-2 days behind real time. 1<sup>st</sup> day of mission data is Jan 19, 2012**
- **V1 VIIRS L1B SDR**
  - Reprocessing started in Oct 2016 and completed in Mar 2017
  - Uses the NOAA/IDPS Mx8.11 version of the operational software and NASA VCST LUT
  - L1B SDR available to science team through NASA LAADS DAAC.
- **V2 NASA L1B**
  - Reprocessing started in Oct 2017 and completed in Mar 2018
  - Uses calibration algorithm and LUT provided by NASA VCST and Geo team
  - Data available to public through NASA LAADS DAAC.
- **NRT processing of V1 Land (using V1 L1B) and V2 L1B is completed typically 2 to 2.5 hours after acquisition of data.**

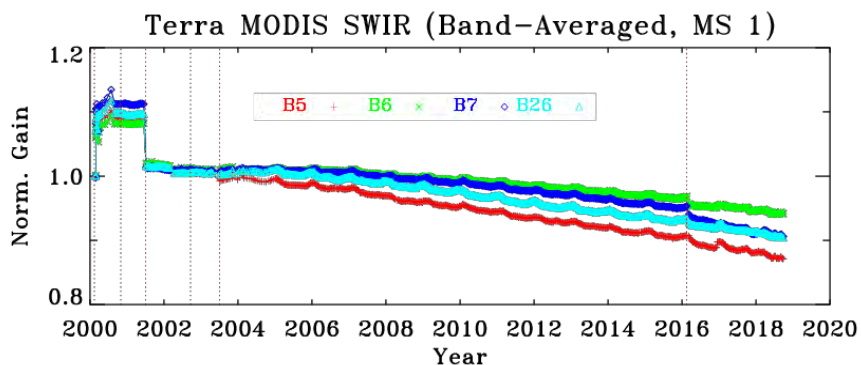
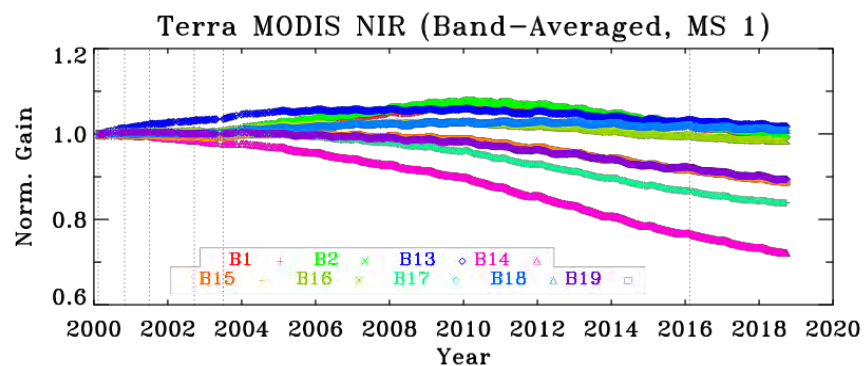
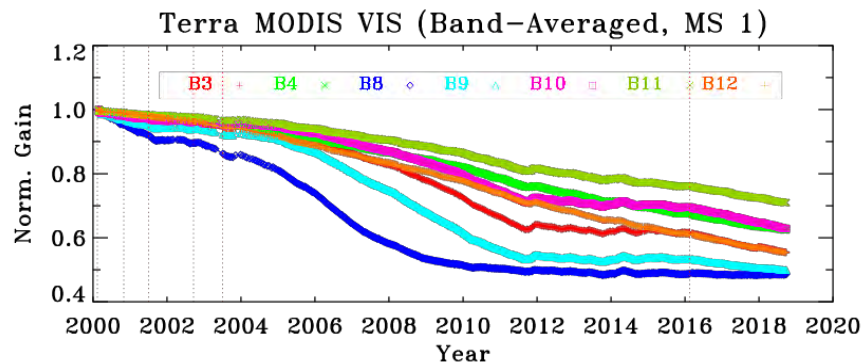
# NOAA-20 VIIRS L1B Processing Status

- **V2 forward processing of NASA L1B are typically 1-2 days behind real time. 1<sup>st</sup> day of mission data is Jan 7, 2018**
  - Currently using pre-launch LUT
  - Data available to science team through NASA LAADS DAAC.
- **V3 release version of J1/SNPP L1B calibration software using post-launch LUT has been tested and verified.**
  - Reprocessing of J1 L1B expected to start in Oct/Nov 2018.
  - To be released to public through NASA LAADS DAAC
- **NRT processing of V2 L1B is completed typically 2 – 2.5 hours after acquisition of data.**
  - Will use the V3 version of the NASA developed L1B software with post-launch LUT when approved for operational processing.

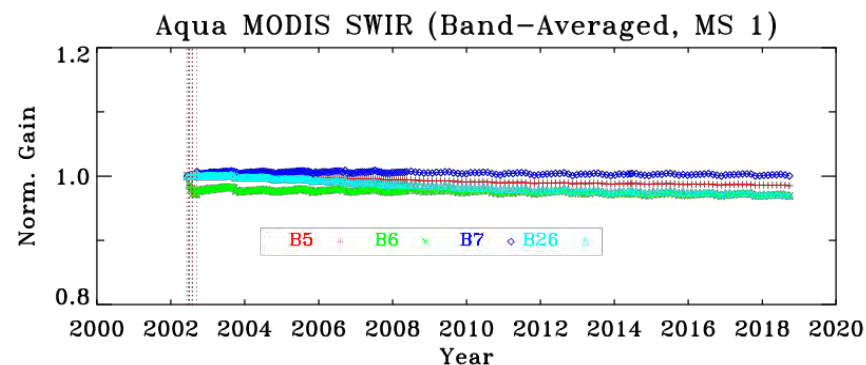
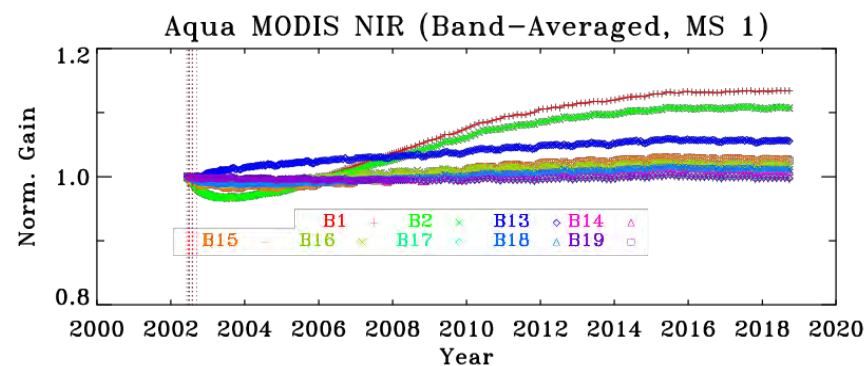
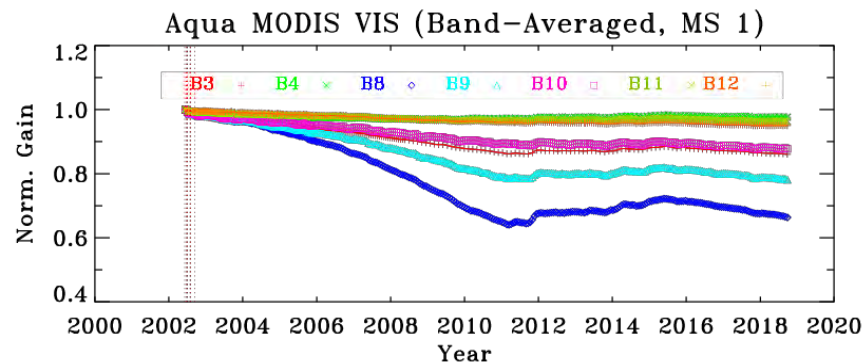
**More details will be presented at the land break-out session**

# MODIS Spectral Band Responses (Gains): RSB

## Terra MODIS



## Aqua MODIS

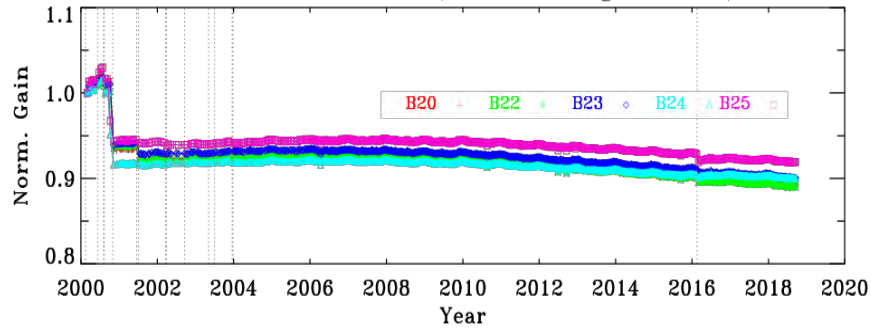




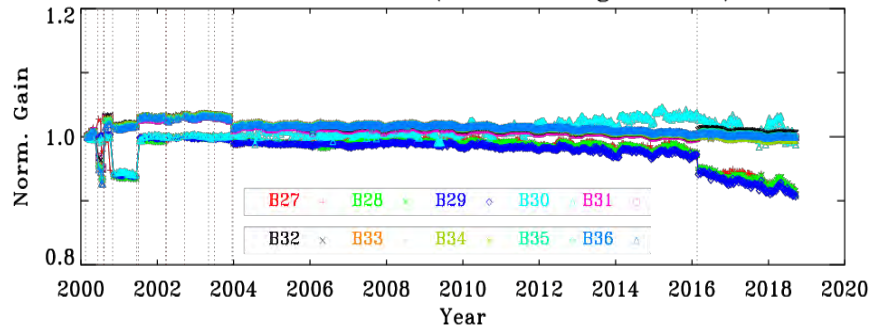
# MODIS Spectral Band Responses (Gains): TEB

## Terra MODIS

Terra MODIS MWIR (Band-Averaged, MS 1)

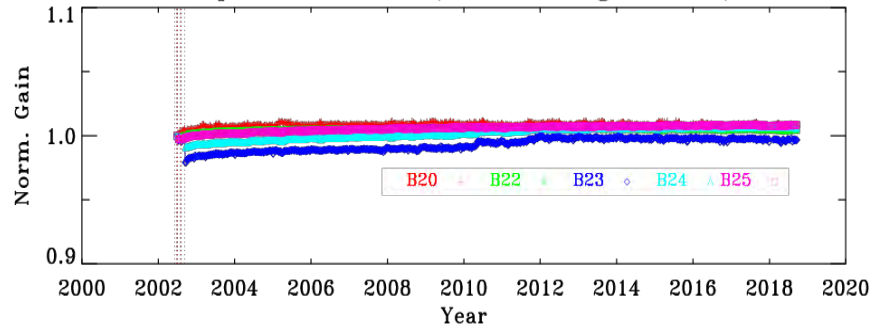


Terra MODIS LWIR (Band-Averaged, MS 1)

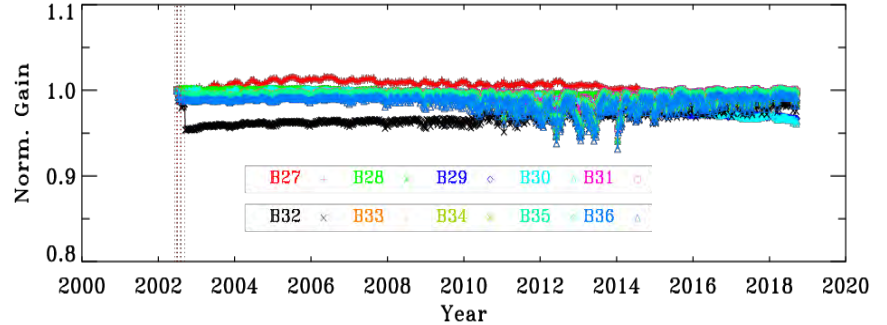


## Aqua MODIS

Aqua MODIS MWIR (Band-Averaged, MS 1)

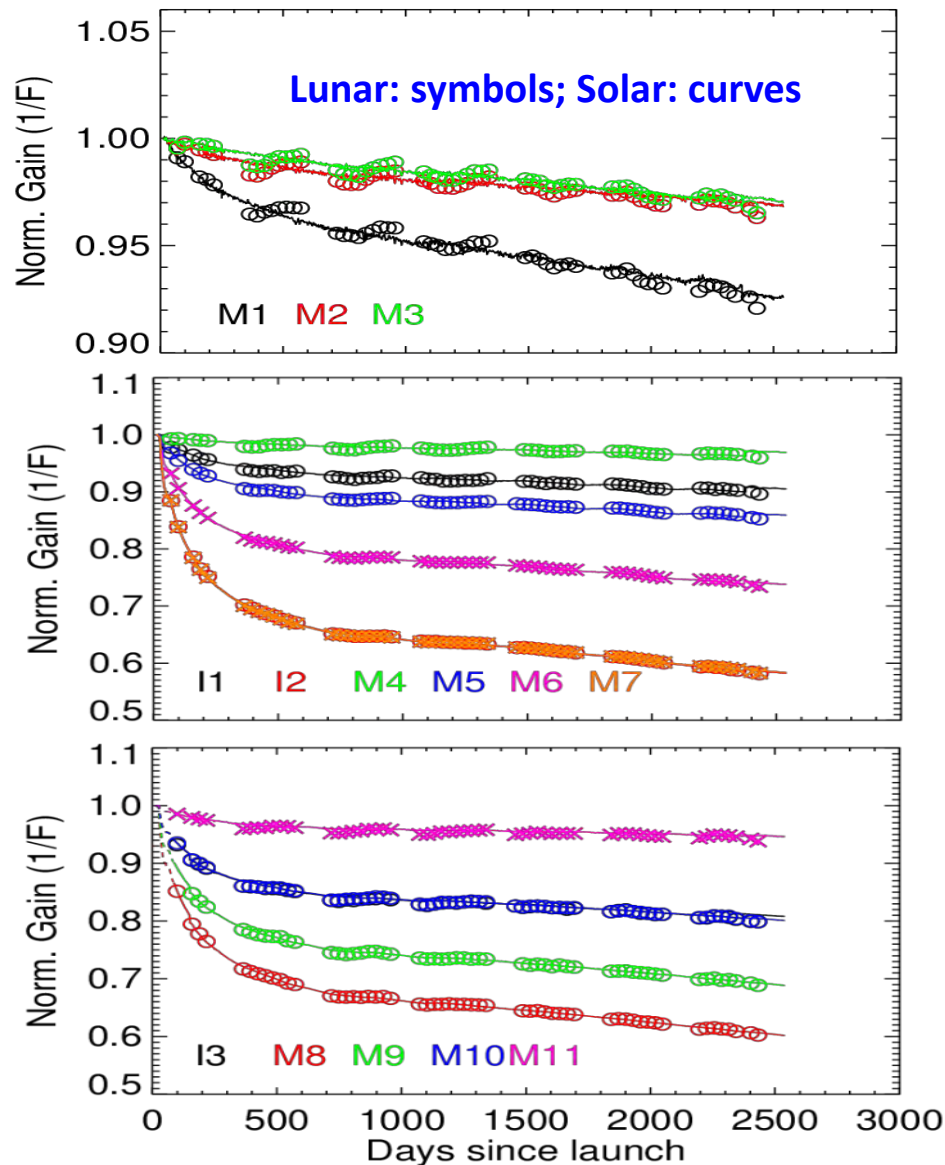


Aqua MODIS LWIR (Band-Averaged, MS 1)

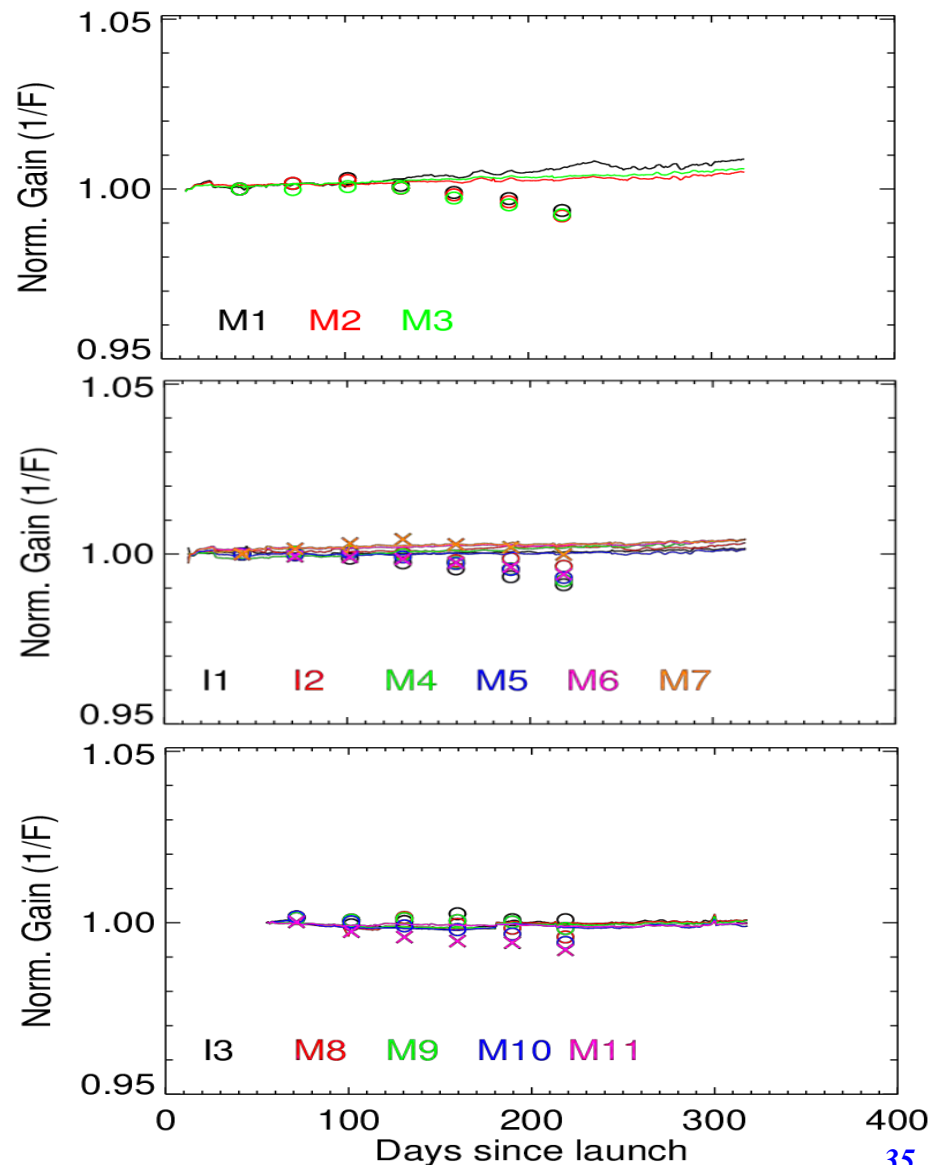


# VIIRS Spectral Band Responses (Gains): RSB

## S-NPP VIIRS



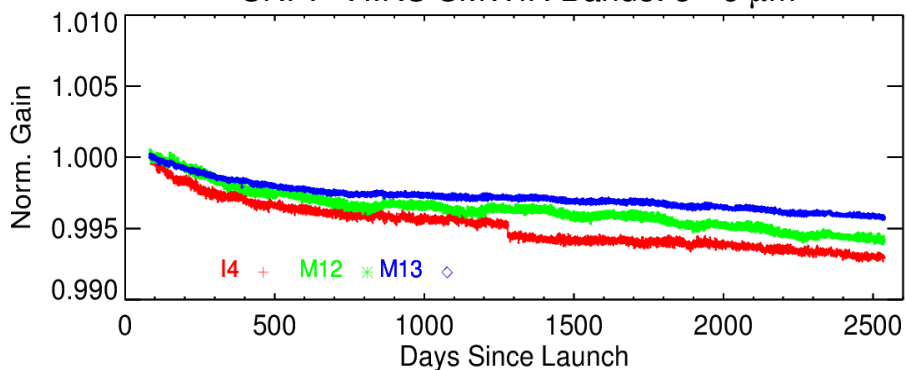
## NOAA-20 VIIRS



# VIIRS Spectral Band Responses (Gains): TEB

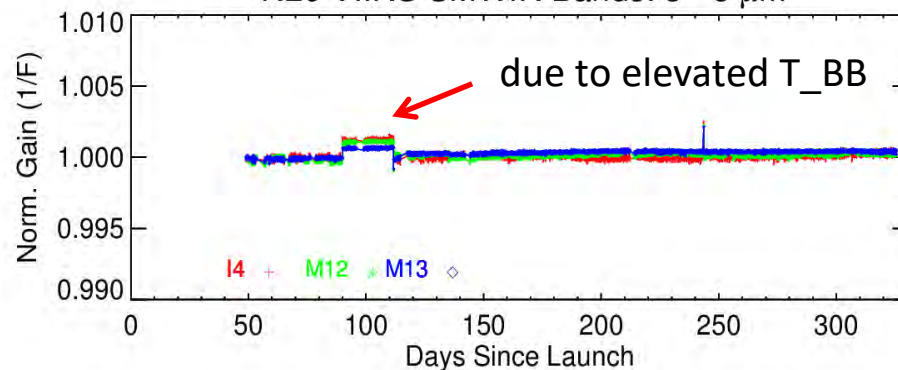
## S-NPP VIIRS

SNPP VIIRS SMWIR Bands: 3 - 5  $\mu\text{m}$

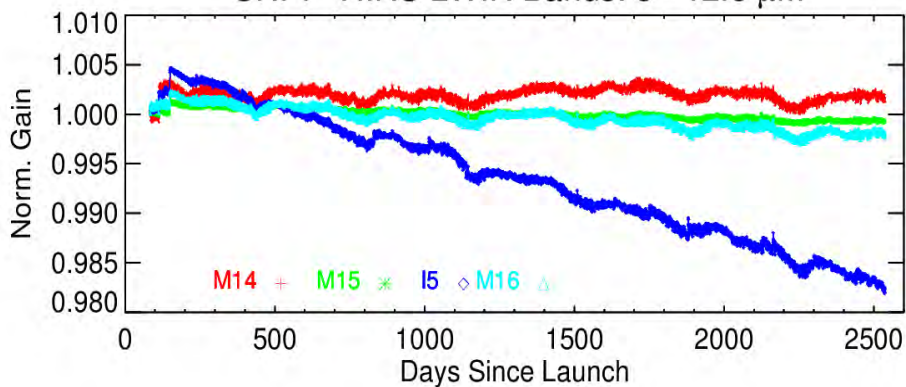


## NOAA-20 VIIRS

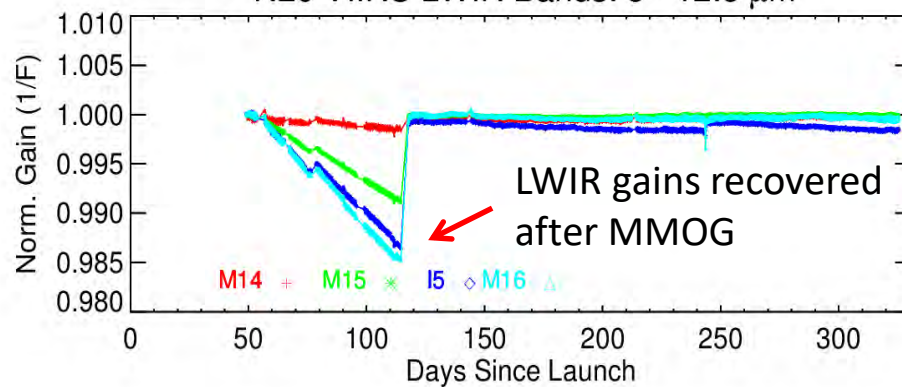
N20 VIIRS SMWIR Bands: 3 - 5  $\mu\text{m}$



SNPP VIIRS LWIR Bands: 8 - 12.5  $\mu\text{m}$



N20 VIIRS LWIR Bands: 8 - 12.5  $\mu\text{m}$



# VIIRS and MODIS Spectral Bands

16 Moderate (radiometric) bands, 5 Imaging bands, 1 DNB

VIIRS			MODIS Substitute		
VIIRS Band	Spectral Range (um)	Nadir HSR (m)	MODIS Band(s)	Range	HSR
DNB	0.500 - 0.900				
M1	0.402 - 0.422	750	8	0.405 - 0.420	1000
M2	0.436 - 0.454	750	9	0.438 - 0.448	1000
M3	0.478 - 0.498	750	3 10	0.459 - 0.479 0.483 - 0.493	500 1000
M4	0.545 - 0.565	750	4 or 12	0.545 - 0.565 0.546 - 0.556	500 1000
I1	0.600 - 0.680	375	1	0.620 - 0.670	250
M5	0.662 - 0.682	750	13 or 14	0.662 - 0.672 0.673 - 0.683	1000 1000
M6	0.739 - 0.754	750	15	0.743 - 0.753	1000
I2	0.846 - 0.885	375	2	0.841 - 0.876	250
M7	0.846 - 0.885	750	16 or 2	0.862 - 0.877 0.841 - 0.876	1000 250
M8	1.230 - 1.250	750	5	SAME	500
M9	1.371 - 1.386	750	26	1.360 - 1.390	1000
I3	1.580 - 1.640	375	6	1.628 - 1.652	500
M10	1.580 - 1.640	750	6	1.628 - 1.652	500
M11	2.225 - 2.275	750	7	2.105 - 2.155	500
I4	3.550 - 3.930	375	20	3.660 - 3.840	1000
M12	3.660 - 3.840	750	20	SAME	1000
M13	3.973 - 4.128	750	21 or 22	3.929 - 3.989 3.929 - 3.989	1000 1000
M14	8.400 - 8.700	750	29	SAME	1000
M15	10.263 - 11.263	750	31	10.780 - 11.280	1000
I5	10.500 - 12.400	375	31 or 32	10.780 - 11.280 11.770 - 12.270	1000 1000
M16	11.538 - 12.488	750	32	11.770 - 12.270	1000



1 DNB



14 RSB  
(0.4-2.3  $\mu\text{m}$ )



Dual Gain Bands:  
M1-M5, M7, M13



7 TEB

**MODIS 33-36**

# MODIS Instrument Operation

- ☺ **No Changes to both Instrument Operation Configurations and OBC Functions since Last Science Team Meeting (details on MCST website)**

## Terra MODIS

- Launch: Dec 18, 1999
- First light: Feb 24, 2000
- A-side: launch - Oct 30, 2000
- B-side: Oct 30, 2000 - June 15, 2001
- A-side: July 02, 2001 - Sept 17, 2002
- A-side electronics & B-side formatter: since Sept 17, 2002
- BB nominally set at 290 K
- SD door fixed at “open” since July 02, 2003
- SRCA operated with 2 10-W lamps since 2006
- CFPA controlled at 83 K (briefly at 85 K: 3-5 Aug 2000)

## Aqua MODIS

- Launch: May 04, 2002
- First light: June 24, 2002
- B-side: launch - present
- BB nominally operated at 285 K
- SD calibration: gradually reduced frequency
- SRCA operated with 2 10-W lamps since 2005 and 1 10-W lamp since 2016
- CFPA controlled at 83 K (small increase of CFPA temperatures since 2007)